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ON THE INTERRELATION OF TEMPERATURE, PRESSURE, AIR DENSITY, AND HUMIDITY

August 1991

Bruce T. Miers

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LABORATORY COMMAND
ATMOSPHERIC SCIENCES LABORATORY
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During military operations in Southwest Asia (SWA), Headquarters, U.S. Armament, Munitions and Chemical Command (AMCCOM), Picatinny Arsenal, New Jersey (AMSMC-QAN-P(D)), requested a usable compilation of meteorological equations on the interrelation of temperature, pressure, air density, and humidity. The Predictive Technology Branch of AMCCOM was appointed by the Director, Command Group, Mid-East Operations, as the coordinator for all activities involving the identification of weapon and ammunition limitations for AMCCOM materials deployed in SWA. These equations were to be used to help define the exposure environment of munitions and materials in SWA. From the equations developed in the report and the supplied computer program, most vapor pressure, humidity, air density, and altimetry computations can be accomplished. Results compare favorably with values in meteorological handbooks.

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1. INTRODUCTION

Recent (1990–1991) military operations in Southwest Asia resulted in the placement of materials and munitions into the most oppressive combinations of heat and humidity in the world. The Persian Gulf is a shallow body of water less than 200 m deep that attains remarkably high temperatures in summer. The average water temperature in July and August is 31.1 °C (88 °F). One of the highest dew points ever recorded was 33.9 °C (93 °F) at Sharjah, Saudi Arabia, which is near Dubai on the southern end of the Persian Gulf. At the northern end of the Persian Gulf exists the most extreme high temperature, high humidity environment on record. On 24 July 1953 at 1400 (LST), the temperature was 48.3 °C (119 °F) and the dew point was 29.4 °C (85 °F), which yields a relative humidity of 34 percent.

This hostile environment could adversely affect the storage life and operability of military equipment. Among the requests from the field for information on environmental conditions, there have been a substantial number regarding the interrelation of temperature, pressure, air density, and relative humidity. This report discusses the basic equations that relate these variables along with simpler approximations that provide the accuracy required for most meteorological operations. A computer code that computes these meteorological parameters is included for completeness. This computer code is not intended to be used for voluminous data input; however, modifications could be made so that all data could be input in one routine and then output the desired results. These equations and codes were supplied to AMSMC–QAN–P(D) to satisfy an immediate need and were not intended for field use.

2. ESTIMATION OF HUMIDITY PARAMETERS

For most meteorological applications, the moisture content of the atmosphere is conveniently measured by means of dry (T) and wet (T_w) bulb temperatures. However, the computation of other measures of humidity such as the dew point (T_d), vapor pressure (e), and relative humidity (RH) can be somewhat complex. Semiempirical equations (Goff and Gratch, 1945) are often used, but for many applications simpler and less accurate equations are sufficient. World Meteorological Organization Publication 8, TP.3 (WMO, 1969) gives the universal psychrometric formula for computation of humidity parameters as the Regnault equation (equation (1)).

$$e = e_w - Ap\,(T - T_w) \tag{1}$$

where e is the vapor pressure, p is air pressure, e_w is the saturation vapor pressure at T_w (wet bulb), T is the dry bulb temperature, and A is the psychrometric coefficient. The saturation vapor pressure is the source of the computational problem. The difficulty lies in the departures from the ideal gas law and the variation of latent heat with temperature. Several papers in the literature give empirical approximations for the saturation vapor pressure (Murray, 1967, and Tabata, 1973, for example). Saturation vapor pressure can be expressed as a function of absolute temperature by the Clausis–Clapeyron equation (equation (2)).

$$\frac{1}{e_s}\frac{de_s}{dT} = \frac{EL}{RT^2} \tag{2}$$

where e_s is the saturation vapor pressure, T is the absolute temperature, L is the latent heat of vaporization of water, R is the gas constant for dry air, and E is the ratio of molecular weight of water vapor to that of dry air. Integration of this equation is difficult because L is not constant, but varies with temperature. If it is assumed that L is a linear function of T then, according to Abbott and Tabony (1985), the saturation vapor pressure can be expressed as in equation (3).

$$e_s = \exp(55.17 - 6803\,T^{-1} - 5.07\ln T) \tag{3}$$

where T is temperature. From Buck (1981), a form for recovering T from the vapor pressure over water is given in equation (4).

$$T = \frac{CZ}{(B - Z)} \tag{4}$$

where $Z = \ln(e_w/a)$ and $a = 6.1121$, $B = 17.368$, and $C = 238.88$ (over ice: $a = 6.1115$, $B = 22.452$, and $C = 272.55$). Equations (3) and (4) appear to be adequate for most meteorological purposes. Wexler (1976) optimized these equations, and equation (5) is a most accurate formulation for e_w, with uncertainty being only a few parts per million (ppm).

$$\begin{aligned} e_w = 0.01\exp[&-2991.2729\theta^{-2} - 6017.0128\theta^{-1} + 18.87643854 \\ &- 0.028354721\theta + 0.17838301 \times 10^{-4}\,\theta^2 - 0.84150417 \times 10^{-9}\,\theta^3 \\ &+ 0.44412543 \times 10^{-12}\,\theta^4 + 2.858487\ln\theta] \end{aligned} \tag{5}$$

where θ is absolute temperature in kelvins. Equation (5) also provides the best available estimate for vapor pressure over supercooled water and can be used for water values below 0 °C. Supercooled conditions are often encountered with cooled mirror hygrometers in which a mirror surface can maintain a layer of water at -15 °C. The equation for saturation vapor pressure over ice is not given in the text but is included in the computer code (see appendix for the "C" program) for completeness. The interested reader is referred to the paper by Wexler (1976) for the exact formulation.

Sometimes an enhancement factor is added to the vapor pressure computation to compensate for the difference in saturation vapor pressure over "pure" water to the saturation vapor pressure over ambient moist air. Hyland (1975) estimated this uncertainty at 1000 mbar to increase from 0.01 percent at 50 °C to 0.06 percent at -50 °C. For vapor pressure and temperature ranges encountered in

Southwest Asia, this enhancement factor is considered superfluous. The interested reader is referred to a paper by Buck (1981) if the factor is considered important. For most meteorological purposes the accuracy required of e_w is that equivalent to an error of 0.1 °C in temperature. Equation (5) easily satisfies this requirement.

3. ESTIMATION OF THE WET BULB FROM THE DRY BULB AND THE DEW POINT

The precision to which the temperature (T) and the dew point (T_d) are reported in the WMO synoptic code messages was increased in 1982 from 1 °C to 0.1 °C. This change made it possible to compute humidity parameters directly from the messages rather than through internal reporting of the wet bulb (T_w). The advantage is increased automation; but the recovery of T_w from T and T_d is required, and this procedure is not straightforward. Estimating T_w from T and T_d is more complex than obtaining T_d from T and T_w. Equation (1) is expressed in terms of the depression of the wet bulb rather than the dew point, and so can only be solved for T_d by using an iterative procedure. A simpler method is to take advantage of the fact that T_w lies between T and T_d. At low temperatures T_w is not much less than T, but at high temperatures T_w is closer to T_d. Hence, the ratio of the wet bulb depression to the dew-point depression always lies between zero and unity and increases with temperature. Abbott and Tabony (1985) give a convenient linear representation of this property in equation (6).

$$\frac{T - T_w}{T - T_d} = 0.34 + 0.006\,(T + T_d) \tag{6}$$

For values of T from -10 °C to +50 °C and dew-point depressions up to 15 °C, errors in T_w from using equation (6) are always less than 0.3 °C. For increased accuracy an iterative approximation method is used in the supplied computer program.

4. ESTIMATION OF ABSOLUTE HUMIDITY, RELATIVE HUMIDITY, AND AIR DENSITY

Calculation of these values begins with a determination of e_s, which requires a knowledge not only of T and T_w but also of e_w at the wet bulb temperature. This can be obtained by replacing T by T_w in equation (3) to yield equation (7).

$$e_w = 6.1070 \exp \frac{17.38\,T_w}{239.0 + T_w} \tag{7}$$

Since $e_s = e_{w(Td)}$, the Regnault equation may be written as

$$e_{w(T_d)} = e_{w(T_w)} - Ap(T - T_w) \tag{8}$$

The ventilation coefficient A is usually taken to be 0.00079 (0.000720 if the wet bulb is frozen). Accurate values of p should be used. Abbot and Tabony (1985) show errors of about 20 percent in e, 2 percent in relative humidity, and 2 °C in T_d if a pressure of 1000 mbar is used when in reality the pressure was 950 mbar. The correct pressure to apply is the site pressure, uncorrected for altitude. The dew point can be calculated from the transposed Magnus (1844) equation for evaporation over water (equation (9)).

$$T_d = \frac{(239.0\,K)}{(17.38 - K)} \tag{9}$$

where K = ln e − ln 6.1070.

The saturation vapor pressure at the dry bulb is then computed so that the relative humidity (RH) may be calculated from equation (10).

$$RH = \frac{e_{s_{T_d}}}{e_{s_T}} \times 100 \tag{10}$$

where e_s is the saturation vapor pressures at T and T_d .

Absolute humidity (AH) is the mass of water vapor per unit volume of atmosphere. The equation of state for water vapor can be written as

$$\rho_{ws} = \frac{(e_s m_v)}{(RT_s)} \tag{11}$$

where ρ_{ws} is the absolute humidity (grams per cubic meter) and the subscript refers to saturation conditions over water. e_s and T_s are the vapor pressure and temperature at saturation and m_v is the mass or weight of the water vapor. Equation (12) is a convenient computational method for determining absolute humidity.

$$AH = \frac{1322.8314}{T} \exp\,[25.22 \times (1.0 - (273.15/T_d) + 5.31 \times \ln (273.15/T_d)] \tag{12}$$

where T and T_d are air temperature (K) and dew-point temperature (K), respectively. AH is expressed in grams per cubic meter.

Specific humidity (q) is defined as the weight of water vapor contained in a unit weight of air. Units of q are usually expressed in grams per gram or grams per kilogram. A simple expression for q is given by equation (13).

$$q = \frac{w}{1 + w} \quad where: \; w = \frac{0.622\,e}{p - e} \tag{13}$$

where e is the vapor pressure at T and p is air pressure (mbar). Units are grams per gram.

The virtual temperature (T_v) is defined as the temperature of dry air having the same total pressure and density as the moist air. An expression for T_v is given by equation (14). p and e have the same meaning as in equation (13).

$$T_v = T(1 + 0.61\,w) \quad where: \; w = \frac{0.622\,e}{p - e} \tag{14}$$

Once T_v is known the air density can be calculated from equation (15) (List, 1958).

$$\rho = 0.34838\,\frac{p}{T_v} \tag{15}$$

where ρ is air density in kilograms per cubic meter, p is site pressure in millibars, and T_v is virtual temperature in kelvins.

5. COMPUTATION OF PRESSURE AND DENSITY ALTITUDES

Pressure altitude (PA) is the height above sea level in the standard atmosphere at which the altimeter setting (A) exists. The PA (in meters) can be computed by using equation (16).

$$PA = \frac{T_s}{a}\,[1 - (A/P_s)^{(1/n)}] + He \tag{16}$$

where T_s is the standard sea level temperature (288.16 K), a is the standard lapse rate (0.0065 °C/m), A is the site altimeter reading (inches mercury [Hg]), P_s is the standard sea-level pressure (29.921 inches Hg), n is a constant with a value of 5.2561, and He is the site elevation in meters above sea level. Restated, pressure altitude is the distance measured from the 29.921 inches hg pressure level, which is the standard datum plane.

Density altitude (DA) is the altitude above sea level characterized by a known air density. Density altitude bears the same relation to pressure altitude as true altitude does to indicated altitude. DA may be computed by using equation (17).

$$DA = 145{,}366\,[1 - 17.326\,(P_m/T_v)^{0.235}] \tag{17}$$

The units of DA are in feet; and A, He, P_s, and n are defined as above for pressure altitude and P_m is defined as

$$P_m = [A^{1/n} - He(P_s)^{1/n}(\frac{a}{T_s})]^n$$

6. SUMMARY

In determining the various measures of humidity, the greatest difficulty lies in evaluating the saturation vapor pressure. This difficulty is related to departures from the ideal gas law and the variation of latent heat with temperature. These departures make the Clausius-Clapeyron equation difficult to integrate analytically. Semiempirical equations by Goff and Gratch (1946) are available for extremely accurate computations of saturation vapor pressure, but for most meteorological purposes this accuracy is superfluous. Equations given in this report are simpler approximations providing the accuracy required for most meteorological applications. A simple iteration routine has been supplied for determining the wet bulb temperature from the temperature and dew point. From the equations and the supplied computer program, most vapor pressure, humidity, air density, and altimetry computations can be accomplished. Results compare favorably with values in meteorological handbooks.

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APPENDIX

"C" PROGRAM

```
/*
```

```
File:     SVP.C

Program:  Saturation Vapor Pressure.

Author:   Kevin K. Lewis, 1991.

Purpose:  SVP computes the saturation vapor pressure of a set of input
          data.  See the provided documentation for a full explanation.

SVP was written for the Weather Data Indegration Branch of the Battle
Weather Data Division of the Atmospheric Sciences Laboratory.

SVP.C was compiled using Borland's Turbo C++ compiler.  It was not
compiled using any C++ options, so it should compile with any Borland
compiler and run properly.

SVP.C should easily port to any system with an ANSI C compatible
compiler.
```

```
*/


#include <stdio.h>
#include <math.h>

void Svp( double *T, double *Tv, double *P );
double Ew( double T );
void Air_Density( double T, double P );
void Temp();
void Wet_T( double T, double Td, double P );
double Dew_Point( double T, double P );
void Density_Altitude( double *T );
void Pressure_Altitude();
int Get_Data( double *data, char param, char *t );
double Convert_Temp( double temp, char type, char need );
double Convert_Pressure( double p, char type, char need );
double Convert_Height( double h, char type, char need );
char Getchar();

/* Define the varaibles. */
double K, ewp, Td, Tw, R, rho;
char numstr[50], ch;


void main()
```

```
{
   double T, Tv, P;
   puts( "                    ┌──────────────────────────────────────────────┐" );
   puts( "                    │        *** Saturation Vapor Pressure ***     │" );
   puts( "                    └──────────────────────────────────────────────┘" );
   puts( "\nInstructions:\n" );
   puts( "When prompted, follow your input by a letter corresponding to the units of" );
   puts( "the input values.  For example, 20 degrees Celsius is entered as 20c (capital" );
   puts( "or lower case 'C'), 293 Kelvin as 293K, 68 degrees Fahrenheit as 68F, 29.92" );
   puts( "inches of mercury as 29.92I, 1013 millibars as 1013m, 1000 feet as 1000F," );
   puts( "and 300 meters as 300M.  Output units are given with the computed value." );

   do {

      Svp( &T, &Tv, &P );

      Air_Density( Tv, P );

      do {
         printf( "\nWould you like to compute the Density Altitude (y/n)? " );
         ch=Getchar();
         if( ch!='y' && ch!='Y' && ch!='n' && ch!='N' ) {
            putch( '\a' );
            ch=0;
         }
      } while( !ch );
      if( ch=='y' || ch=='Y' )
         Density_Altitude( &T );

      do {
         printf( "\nWould you like to compute the Pressure Altitude (y/n)? " );
         ch=Getchar();
         if( ch!='y' && ch!='Y' && ch!='n' && ch!='N' ) {
            putch( '\a' );
            ch=0;
         }
      } while( !ch );
      if( ch=='y' || ch=='Y' )
         Pressure_Altitude();

/*
   ... We are done with all the computations.  Find out if the user has some
   other stuff to do.
*/
      do {
         printf( "\n\nWould you like to compute additional values (y/n)? " );
         ch=Getchar();
         if( ch!='y' && ch!='Y' && ch!='n' && ch!='N' ) {
            putch( '\a' );
            ch=0;
         }
      } while( !ch );
   } while( ch=='y' || ch=='Y' );

}
```

```
void Svp( double *T, double *Tv, double *P )

{
   double AH, RH, q, w, e;
/* Get the dry bulb temperature. */
   puts( '\n' );
   do {
      printf( 'Input the dry bulb temperature T followed by K, C, or F: ' );
   } while( Get_Data( T, 'T', &ch )==-1 );
   *T=Convert_Temp( *T, ch, 'K' );

/* Get the pressure. */
   do {
      printf( 'Input the pressure P followed by I or M (default=1013.25mb): ' );
   } while( Get_Data( P, 'P', &ch )==-1 );
   *P=Convert_Pressure( *P, ch, 'M' );

   do {
      printf( '\nDo you have the dew point temperature (y/n)? ' );
      ch=Getchar();
      if( ch!='y' && ch!='Y' && ch!='n' && ch!='N' ) {
         putch( '\a' );
         ch=0;
      }
   } while( !ch );
   putchar( 10 );
   if( ch=='y' || ch=='Y' ) {
      do {
         printf( 'Input the dew point temperature Td followed by K, C, or F: ' );
      } while( Get_Data( &Td, 'T', &ch )==-1 );
      Td=Convert_Temp( Td, ch, 'K' );
      e=Ew( Td );
      Wet_T( *T, Td, *P );
   }
   else {
      do {
         printf( 'Input the wet bulb temperature Tw followed by K, C, or F: ' );
      } while( Get_Data( &Tw, 'T', &ch )==-1 );
      Tw=Convert_Temp( Tw, ch, 'K' );
      Td=Dew_Point( *T, *P );
      printf( '\nThe Dew Point Temperature is  \t\t%10.4f [Kelvin]\n', Td );
      printf( '                               \t\t%10.4f [Celcius]\n', Convert_Temp( Td, 'K', 'C' ) );
      printf( '                               \t\t%10.4f [Fahrenheit]\n', Convert_Temp( Td, 'K', 'F' ) );
      e=Ew( Td );
   }

/* Compute 'ewp' */
   ewp=Ew( *T );
   printf( '\nThe Saturation Vapor Pressure e(T) is \t%10.4f [millibars]\n', ewp );

   printf( 'The Saturation Vapor Pressure e(Td) is \t%10.4f [millibars]\n', e );
```

```
/* Compute the relative humidity. */
   RH=e/ewp*100;
   printf( "The Relative Humidity is \t\t%10.4f%%\n", RH );

/* Compute the absolute humidity. */
   AH=( 1322.8314/(*T) )*exp( 25.22*( 1.0 - ( 273.15/Td ) ) + 5.31*log( 273.15/Td ) );
   printf( "\nThe Absolute Humidity is \t\t%10.4f [grams per cubic meter]\n", AH );

/* Compute the virtual temperature. */
   w=0.622*ewp/( *P - ewp );
   q=w/( 1.0 + w );
   printf( "The Specific Humidity is \t\t%10.4f [grams per gram]\n", q );
   *Tv=*T*( 1.0 + 0.61*w );
   printf( "The Virtual Temperature is \t\t%10.4f [Kelvin]\n", *Tv );

}


double Ew( double T ) /* T must be in K, and P must be in mB. */

{
   double satvp;
/*
   The second equation is used for saturation vapor pressure over ice.  If you
   wish to use this equation, remove the comment markers on the indicated lines.
*/
/* Remove this line.
   if( T>=273.15 )
   Remove this line. */

      satvp=0.01*exp( -2991.2729/( T*T ) - 6017.0128/T + 18.87643854 -
         0.028354721*T + 0.17838301e-4*T*T - 0.84150417e-9*T*T*T +
         0.44412543e-12*T*T*T*T + 2.858487*log( T ) );

/* Remove this line.
   else
      satvp=0.01*exp( -5865.3696/T + 22.241033 + 0.013749042*T -
         0.34031775e-4*T*T + 0.26967687e-7*T*T*T + 0.6918651*log( T ) );
   Remove this line. */

   return satvp;

}

/* Compute the air density. */
void Air_Density( double Tv, double P )

{
   double rho;
   rho=0.34838*P/Tv;
   printf( "\nThe Air Density is \t\t\t%10.4f [kilograms per cubic meter]\n", rho );

}
```

```
/* Compute the dew point. */
double Dew_Point( double T, double P )

{
   double A=0.000799, es, e, K;
   T -= 273.16; Tw -= 273.16;   /* convert to deg C */
   es=6.107*exp( 17.38*Tw/( 239.0 + Tw ) );
   e = es - A*P*( T - Tw );
   K = log( e ) - log( 6.1070 );
/* printf("\ne, es, K, P, T, Tw = %7.3f, %7.3f, %7.3f, %8.3f, %7.3f, %7.3f\n",
          e, es, K, P, T, Tw); */
   return ( 239.0*K )/( 17.38 - K ) + 273.16;

}


void Wet_T( double T, double Td, double P )

{
   int times=0;
   double tw0, F, Fp, dif;
   double A, a, b, c;
   T=Convert_Temp( T, 'K', 'C' );
   Td=Convert_Temp( Td, 'K', 'C' );
   tw0=0.5*( T + Td );
   do {
      if( tw0)=0.0 ) {
         A=0.000799;
         a=17.38;
         b=239.0;
      }
      else {
         A=0.00072;
         a=22.44;
         b=272.4;
      }
      c=6.107*exp( a*Td/( b + Td ) ) + A*P*T;
      F = 6.107*exp( a*tw0/( b + tw0 ) ) + A*P*tw0 - c;
      Fp = 6.107*a*b/( ( b + tw0 )*( b + tw0 ) )*exp( a*tw0/( b + tw0 ) ) + A*P;
      dif=F/Fp;
      do {
         dif=0.5*dif;
        } while(fabs(dif/tw0))=0.5);
      tw0 = tw0 - dif;
      if( times++)20 ) {
         puts( "\nWarning: possible error in computing wet bulb temperature--20 iterations done." );
         break;
      }
    } while( fabs( dif ))=0.001 );  /* If it's accurate enough; stop. */
    printf( "\nThe wet bulb temperature is \t\t%10.4f [Celsius]\n", tw0 );
    printf( "                                \t\t%10.4f [Celsius]\n", Convert_Temp( tw0, 'C', 'K' ) );
    printf( "                                \t\t%10.4f [Fahrenheit]\n", Convert_Temp( tw0, 'C', 'F' ) );
    Tw=tw0;
```

```
}

void Density_Altitude( double *T )

{
   double r=.006, a=.0065, n=5.2561, Ps=29.921, Ts=288.16;
   double Alt, He, rho_h, Pm, Tv;
   char numstr[50];
   printf( "\nInput T followed by K, C, or F (default is original input=%7.2fK): ", *T );
   if( Get_Data( T, 'T', &ch )!=-1 )
      *T=Convert_Temp( *T, ch, 'K' );
   Tv = -0.288 + ( 9.0/5.0 )*(*T)*( 1.0 + 1.60779*r )/( 1.0 + r );
   do {
      printf( "Input Site Pressure Uncorrected followed by I or M: " );
   } while( Get_Data( &Alt, 'P', &ch )==-1 );
   Alt=Convert_Pressure( Alt, ch, 'I' );
   do {
      printf( "Input site elevation followed by M or F: " );
   } while( Get_Data( &He, 'H', &ch )==-1 );
   He=Convert_Height( He, ch, 'M' );
   Pm=pow( pow( Alt, 1.0/n ) - He*pow( Ps, 1.0/n )*( a/Ts ), n );
   rho_h=145366.0*( 1.0 - pow( 17.326*( Pm/Tv ), 0.235 ) );
   printf( "The Density Altitude is \t\t%10.4f [feet]\n", rho_h );
   printf( "                          \t\t%10.4f [meters]\n", Convert_Height( rho_h, 'F', 'M' ) );

}


void Pressure_Altitude()

{
   double PA, Ts, a, A, Ps, n, He;
   Ts=288.16;
   a=0.0065;
   puts( "\n" );
   do {
      printf( "Input the Altimeter Value followed by I or M: " );
   } while( Get_Data( &A, 'P', &ch )==-1 );
   A=Convert_Pressure( A, ch, 'I' );
   do {
      printf( "Input the site elevation followed by M or F: " );
   } while( Get_Data( &He, 'H', &ch )==-1 );
   He=Convert_Height( He, ch, 'M' );
   Ps=29.921;
   n=5.2561;
   PA=( Ts/a )*( 1.0 - pow( A/Ps, 1.0/n ) ) + He;
   printf( "The Pressure Altitude is \t\t%10.4f [meters]\n", PA );
   printf( "                          \t\t%10.4f [feet]\n", Convert_Height( PA, 'M', 'F' ) );

}
```

```
int Get_Data( double *data, char param, char *type )

{
   int len;
   double tmp;
   char t[50];
   gets( t );
   if( strcmp( t, "" )==0 ) {
      if( param=='P' ) {
         *data=1013.25;
         *type='M';
         return 0;
      }
      else
         return -1;
   }
   len=strlen( t );
   *type=t[len-1];
   switch( param ) {
      case 'T':
         if( *type!='C' && *type!='c' && *type!='K' && *type!='k' && *type!='F' && *type!='f' )
            return -1;
         break;
      case 'P':
         if( *type!='M' && *type!='m' && *type!='I' && *type!='i' )
            return -1;
         break;
      case 'H':
         if( *type!='M' && *type!='m' && *type!='F' && *type!='f' )
            return -1;
         break;
   }
   t[len-1]='\0';
   *data=atof( t );
   tmp=Convert_Temp( *data, *type, 'C' );
   if( param=='T' ) {
      if( tmp<-100.0 || tmp>100.0 ) {
         puts( "Temperature is out of range.  Enter a new temperature, -100°C<T<100°C" );
         return -1;
      }
   }
   return 0;

}


double Convert_Temp( double temp, char type, char need )
```

```
{
   switch( need ) {
      case 'K':
         switch( type ) {
            case 'k':
            case 'K':
               return temp;
            case 'f':
            case 'F':
               return 5.0/9.0*( temp - 32.0 ) + 273.15;
            case 'c':
            case 'C':
               return temp + 273.15;
         }
      case 'C':
         switch( type ) {
            case 'k':
            case 'K':
               return temp - 273.15;
            case 'f':
            case 'F':
               return 5.0/9.0*( temp - 32.0 );
            case 'c':
            case 'C':
               return temp;
         }
      case 'F':
         switch( type ) {
            case 'k':
            case 'K':
               return 9.0/5.0*( temp - 273.15 ) + 32.0;
            case 'c':
            case 'C':
               return 9.0/5.0*temp + 32.0;
            case 'f':
            case 'F':
               return temp;
         }
   }
   return -1;
}
```

```
double Convert_Pressure( double p, char type, char need )

{
   switch( need ) {
      case 'I':
         switch( type ) {
            case 'i':
            case 'I':
               return p;
            case 'm':
            case 'M':
               return p/33.86;
         }
      case 'M':
         switch( type ) {
            case 'i':
            case 'I':
               return 33.86*p;
            case 'm':
            case 'M':
               return p;
         }
   }
   return -1;

}


double Convert_Height( double h, char type, char need )

{
   switch( need ) {
      case 'M':
         switch( type ) {
            case 'f':
            case 'F':
               return h*0.3048;
            case 'm':
            case 'M':
               return h;
         }
      case 'F':
         switch( type ) {
            case 'f':
            case 'F':
               return h;
            case 'm':
            case 'M':
               return h*3.280839895;
         }
   }
   return -1;
```

```
}

char Getchar()

{
   char c;
   c=getchar();
   fflush( stdin );
   return c;

}
```

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